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THE MADISON SQUARE GARDEN DISPERSION STUDY (MSG05) METEOROLOGICAL DATA DESCRIPTION

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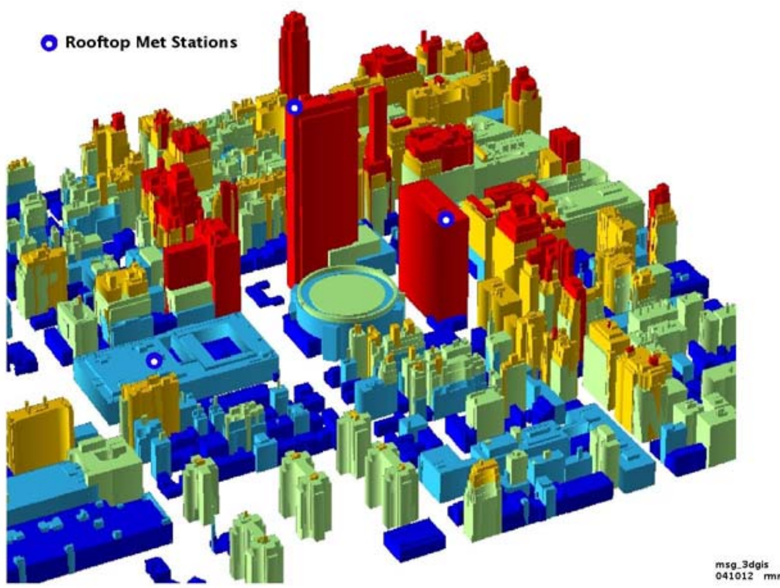
Abstract

MSG05 was a study of atmospheric transport and dispersion in the deep urban canyons of Midtown New York City, in the area of Madison Square Garden. This downtown area is considered to be a prime target for terrorist activities, and has one of the largest commuter populations in the world. Little is known about air flow and hazardous gas dispersion in such scenarios, since previous urban field experiments have focused on small to medium sized cities with much smaller street canyons.

On March 10 and 14, 2005, a series of Perfluorocarbon Tracer (PFT) tracers were released and tracked with about 30 sampling stations at radial distances of about 0.2 and 0.4 km, with vertical profiles near a 250 m tall building (One Penn Plaza). Meteorological stations collected wind data in the MSG vicinity, at street level and rooftop level. MSG05 is expected to provide useful information on rapid vertical dispersion will assist in planning for more extensive studies.

This data release is being made available to a restricted group of key scientists who have worked on the project. Part of the QA program involves feedback from scientists and modelers who are working on this study. This document describes the meteorological component of the project. The file organization and metadata are detailed so that a researcher can work with the data sets.



Data from Vexcel Inc. Figure was provided by Austen Ivey, LANL, Sep 2004

[1]The meteorological team is listed on page 32

The Madison Square Garden Dispersion Study (MSG-05)
Meteorological Data Report

R. Michael Reynolds
Brookhaven National Laboratory

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1 Introduction

The Madison Square Garden Dispersion Experiment (MSG-05) took place in the neighborhood of the Madison Square Garden in central Manhattan, New York City, in March 2005. Hanna et al. (2004) reviewed the scientific goals for the project. MSG-05 was the first dispersion experiment in the Department of Homeland Security (DHS) Urban Dispersion Program (UDP).

The primary objective of the fouryear (20042007) New York City Urban Dispersion Program (UDP) (Allwine, 2004) is to enhance NYCs emergency capabilities for responding to potential airborne releases of harmful contaminants. This objective is to be accomplished: 1) by improving the permanent network of wind stations in and around NYC to better estimate where contaminants may travel, 2) by conducting field studies in NYC to advance knowledge about the movement of contaminants in and around NYC and into and within building interiors, 3) by improving and validating computer models that simulate the atmospheric movement of contaminants in urban areas using data collected from the field studies, and 4) by transferring the improved capabilities to NYC emergency agencies. This program is primarily sponsored by the U.S. Department of Homeland Security with additional support from the U.S. Department of Defense Defense Threat Reduction Agency, the U.S. Department of Energy, and the U.S. Environmental Protection Agency.

During each IOP, six different species of Perfluorocarbon Tracer (PFT) tracers were released from five different release locations. Two gasses were released from one site in order to have a measure of the repeatability of the tracer method. The dispersing plume was tracked with about 30 sampling stations at radial distances of about 0.2 and 0.4 km (Watson, 2005). The six PFTs were measured by batterypowered samplers attached to light poles at about threemeters above ground at each of 21 locations extending out to 400 meters from MSG. To determine the vertical extent of the tracer plume, ten portable tracer samplers were placed at five locations on surrounding buildings. Tracer samplers were located in Penn Station to give an indication of the infiltration of tracers into Penn Station, and tracer samples were collected using personal tracer samplers that were carried by individuals who walked in and around the MSG area and Penn Station.

This document provides details on the meteorological data that were collected during by Brookhaven National Laboratory (BNL) during MSG05. The meteorological data set is divided into three subsets with names given below,

1. MESO. A mesoscale array of meteorological stations. Both existing stations of acceptable quality and specially deployed stations were employed in the MSG05 mesonet data set. The mesonet instrumentation was deployed before the first IOP and operated for a considerable time after IOP2.

2. IOP1. The first Intensive Operation Period (IOP) was conducted on 20050310 from 08:00 to 14:00 Eastern Standard Time (see sectin 1.1 below). During each IOP, six special streetlevel meteorological stations and three setback stations were operated in the vicinity of MSG. Setback stations (Section 4.3)

were located on two elevated locations on One Penn Plaza and on an awning at the Eigth Ave. entrance to the New York Hotel.

3. IOP2. The second IOP took place on 2005-03-14 from 08:00 to 14:00 in exactly the same manner as the first.

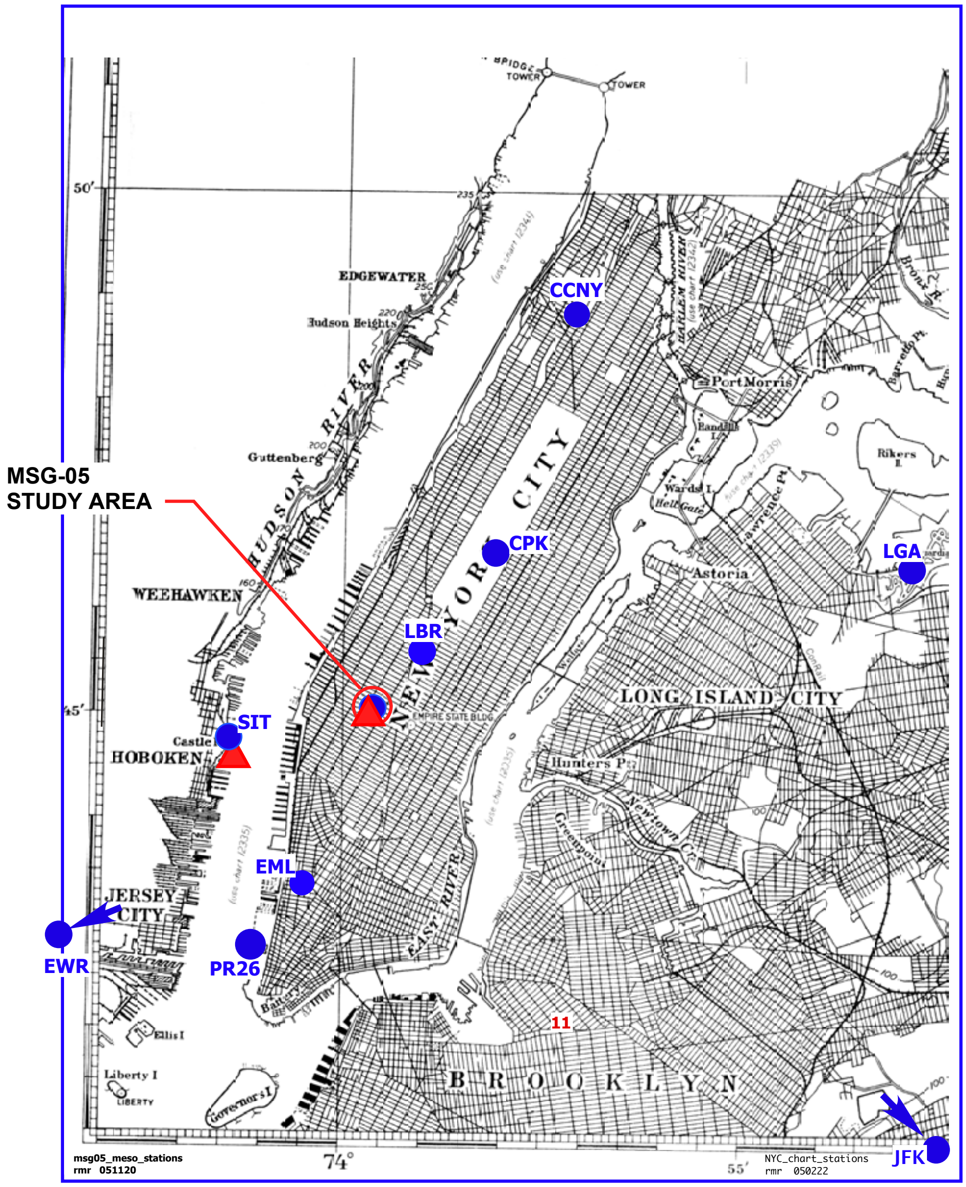


Figure 1: The mesonet stations used in the MSG-05 data set are shown on this marine chart.

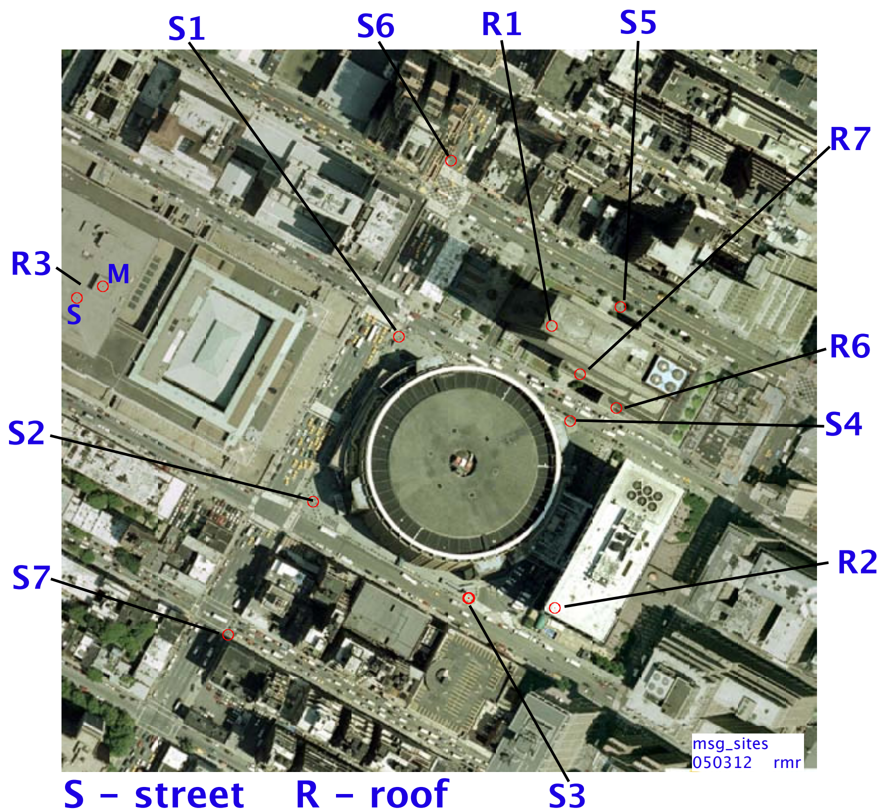


Figure 2: Locations of MSG-05 meteorological stations.

1.1 Time Recording and Averaging

In this data set, all dates and times are recorded and reported in Eastern Standard Time, unless otherwise specified. The EST time zone is -5 hours from Greenwich.

In general time is written from year to seconds left to right. For example a time of 20050310,072634 is equal to, in American format, 10 March 2005 7:26:34.

For all averaged data sets, the date/time mark represents the center of the averaging time. For instance, if an averaging interval is 300 seconds (5 minutes), the 0900 h average is derived from data samples from 085230 to 090230.

1.2 Organization of this report

This meteorological data report is organized along the same lines as the actual data archive file (see 2). Each observation station is described in Section 3 without regard to the data taken there. Similarly, the instrumentation is described in a general way in Section 4. Having described the locations and instruments, the different data sets are described in Section 6. There are three data sets in MSG-05: (1) MESO, the mesoscale network of rooftop installations and external data sets that we, more or less, continuously operating over the entire experiment period. (2) IOP1, the first tracer release exercise that occured on 10 March, and (3) IOP2, the second tracer release that occured on 14 March. Data collection and processing is described in Section 7 for each instrument system. The data quality assurance is reviewed in Section 8. The results are, as advertised, preliminary, and are presented here to provide some overview of the data set that can be used for further analysis by others.

2 Data Organization

The two goals of this technical report are to provide a complete description of the meteorological measurement sub-task to the MSG-05 experiment, and to provide a description of the data set that accompanies this report.

2.1 Data processing levels

We follow a common practice by segregating our data into three levels.

Level 0 Level 0 data are the raw data collected by whatever recording device is available. The raw 10 Hz data from the 3DSonic instrument are included here. Archive ASOS data downloaded from the NWS or other on line sources are collected here exactly as they came. In some cases raw level 0 data are cleaned to remove obviously bad records, spikes, and dropouts. As the original data are not altered, these files remain in the level 0

Level 1 The raw data becomes level 1when they are processed by applying calibration coefficients, wind direction rotations, and any corrections to produce data in true physical units.

Level 2 When the level 1 data are processed to produce "derived" variables or as different level 1 or level 2 data sets are combined, the data are classified as level 2.

2.2 Identification Codes

In order to have a reasonable working environment, a set of ID codes has been developed in order to make unambiguous reference to any element of the project. A table of project ID codes is given below.

File and folder names that belong to a particular ID will begin with the ID followed by an underscore. For example, a folder might be named `iop1_10MarchRelease` and one knows that this folder contains level 1 or level 2 data from this IOP.

Table 1: A table of identification codes (ID) for different elements of the MSG-05 project.

EXPERIMENT	
`msg`	Overall experiment, MSG-05
DATA SEGMENTS	
`meso`	Continuous data over the experiment time period.
`iop1`	The first tracer release data set, 10 March 2005.
`iop2`	The second tracer release data set, 14 March 2005.
LOCATIONS	
`ccny`	CCNY roof
`cpk`	Central Park, Fort Belvedere
`eml`	Environmental Measurements Laboratory, roof
`ewr`	Newark Airport, ASOS site
`fok`	Westhampton Airport, ASOS site
`hpn`	White Plains Airport, ASOS site
`hwv`	Shirley Airport, ASOS site
`isp`	Islip Airport, ASOS site
`jfk`	Kennedy Airport, ASOS site
`lbr`	Lehman Brothers roof site
`lga`	LaGuardia Airport, ASOS site
`p26`	Pier 26, Hudson River site
`r1`	One Penn Plaza roof
`r2`	Two Penn Plaza roof
`r3a`	Farley Post Office, utility roof
`r3b`	Farley Post Office, maun roof (sodar)
`r6`	One Penn Plaza setback, 7th floor
`r7`	One Penn Plaza setback, 12th floor
`s1`	Street site, NW corner of MSG
`s2`	Street site, SW corner of MSG
`s3`	Street site, SE corner of MSG
`s4`	Street site, NE corner of MSG
`s5`	Street site, 34th Street in front of OPP
`s6`	NY Hotel overhang on 8th Ave.
`s7`	Street site, 8th Ave at 30th St, SE corner
`sit`	Stevens Institute of Technology, Howe Center roof

Table 2: A table of identification codes (ID) for different stations of the MSG-05 project. Notice that locations and stations are separate and distinct. In many cases, a location can have more than one station, for example the location `sit`, the roof of the Howe Center at Stevens Institute of Technology, has two stations, `sit1`, the meteorological station operated by the university, and `sit2`, the miniSodar operated as part of the MSG-05 experiment.

STATION IDENTIFICATION CODES

ID	DESCRIPTION	ΔT	MEDIA
`ccny`	NOAA GPS Met station	1 min	html
`cpk`	Central Park, ASOS	60 min	ftp
`eml`	DCNet station	15 min	ftp
`ewr`	Newark Airport, ASOS site	60 min	ftp
`fok`	Westhampton Airport, ASO	60 min	ftp
`hpn`	White Plains Airport, ASOS	60 min	ftp
`hwv`	Shirley Airport, ASOS	60 min	ftp
`isp`	Islip Airport, ASOS	60 min	ftp
`jfk`	Kennedy Airport, ASOS	60 min	ftp
`lbr`	Lehman Brothers DCNet	15 min	ftp
`lga`	LaGuardia Airport, ASOS	60 min	ftp
`p26`	SIT network, Pier 26, Hudson River	5 min	html
`r1`	One Penn Plaza, 10 Hz 3DSonic	10 Hz	laptop
`r2`	Two Penn Plaza, 10 Hz 3DSonic	10 Hz	laptop
`r3a`	Farley Post Office, utility roof	1 min	UHF coms
`r3b`	Farley Post Office, maun roof (sodar)	1 min	laptop
`r6`	OPP setback, 7th floor, 10 Hz 3DSonic	10 Hz	laptop
`r7`	OPP setback, 12th floor, 10 Hz 3DSonic	10 Hz	laptop
`s1a`	Street site, 10 Hz 3DSonic	10 Hz	laptop
`s1b`	Street site, WXT510 2DSonic	3 sec	laptop
`s2`	Street site, 10 Hz 3DSonic	10 Hz	laptop
`s3`	Street site, 10 Hz 3DSonic	10 Hz	laptop
`s4a`	Street site, 10 Hz 3DSonic	10 Hz	laptop
`s4b`	Street site, WXT510 2DSonic	3 sec	laptop
`s5`	Street site, 10 Hz 3DSonic	10 Hz	laptop
`s6`	NY Hotel, 10 Hz 3DSonic	10 Hz	laptop
`s7`	Street site, 10 Hz 3DSonic	10 Hz	laptop
`sit1`	SIT, Howe Center	5 min	html
`sit2`	SIT, Howe Center, sodar	1 min	laptop

2.3 Directory Tree

Table 3: level 0 folder organization.

msg_level0	All raw and cleaned raw data files are stored here.
cpk2005	ASOS station for Central Park for 2005
ewr2005	ASOS station for Newark airport for 2005
jfk2005	ASOS station for Kennedy airport for 2005
lga2005	ASOS station for LaGuardia airport for 2005
r1_opp	Meso station on One Penn Plaza roof
rs_2pp	Meso Station on Two Penn Plaza Roof
r3a_FarleyPO_met	Meso station on the Farley Post Office roof
r3b_FPO_sodar	miniSodar on the FPO roof
r6_opp_7thfloor	3DSonic station on OPP 7th floor overhang
r7_opp_12thfloor	3DSonic station on OPP 12th floor overhang
s1_nw_msg	ASOS station for JFK airport for 2005
s2_sw_msg	ASOS station for JFK airport for 2005
s3_se_msg	ASOS station for JFK airport for 2005
s4_ne_msg	ASOS station for JFK airport for 2005
s5_34thSt	ASOS station for JFK airport for 2005
s6_NYHotel	ASOS station for JFK airport for 2005
s7_8thAve_32nd	ASOS station for JFK airport for 2005
sit1_met	ASOS station for JFK airport for 2005
sit2_sodar	ASOS station for JFK airport for 2005
msg	Metadata, level 1 and level 2 time series, ...
analysis	All preliminary analysis results
field	data from the post-experiment field intercomparison
INFO_msg.txt	Information file for the MSG-05 experiment. (See below)
INSTRUMENTS	Descriptions of instruments and hardware
3mtower	Describe the 3-m street station towers.
6mtower	Describe the 6-m roof station towers.
miniSodar	Describe the AV miniSodar system.
rmy3d	Describe the R.M. Young 3DSonic and data collection system.
setback	Describe the setback frame for wall deployments.
wxt510	Describe the Vaisala WXT510 weather station with 2DSonic.
iop1_050310	Results from the first IOP
ccny	A subset of the ccny meso data set.
r1	A subset of the r1 meso data set.
...	...
iop2_050314	Results from the second IOP
ccny	A subset of the ccny meso data set.
r1	A subset of the r1 meso data set.
...	...
LOCATION_INFO	Location metadata (See Table 1)
jfk	Location info for the JFK ASOS site. Photos, etc.
...	...
meso	Results from the mesonet data set
r1_OnePennPlaza_roof	Full level 1 data sets from OPP roof.
...	...
msg_datareport	All images and source for this document
sw	All data processing software for the MSG-05 project
matlab	matlab routines
sodar	PERL and Matlab routines for sodar processing
...	...

2.4 INFO Files

We use simple text INFO files as the most reliable way of keeping track of metadata. All metadata INFO files are located with the particular data set in the archive. For instance if we want to know about the location with ID `r1` we look at the INFO file `msg/LOCATION_INFO/r1_*/INFO_r1.txt` and find:

```
STATION ID :  r1
LAST EDIT DATE : 2005,11,22
SHORT DESCRIPTION : One Penn Plaza roof
ADDRESS : 446 Eighth Ave.
EXPERIMENT NAME: msg
OWNER : BNL
POINT OF CONTACT : Scott Smith, 631-344-7197, ssmith@bnl.gov
LAT :  40.751681
LON : -73.993250
SOURCE, POSITION : DOITT NYC GIS BASE MAP
GROUND ELEVATION (ASL) : 10.7
SOURCE ELEVATION :  DOITT Planimetric shapefile, email from a. cialella 040423
HEIGHT OF ANEMOM (AGL) : 233
SOURCE HEIGHT : Laser binoculars view to pavement
SENSOR LIST : RMY3D
DESCRIPTION :
 The station was mounted in the SW corner of the rooftop and well away
 from the HVAC exhaust fans.
 Roof height above ground: 57 floors.  The laser binocs reported
 a distance from eye level to the sidewalk below of 227 m.  This station will be
 operated for the duration of the experiment.
```

INFO files provide a convenient means of entering new information or editing data.

3 Locations

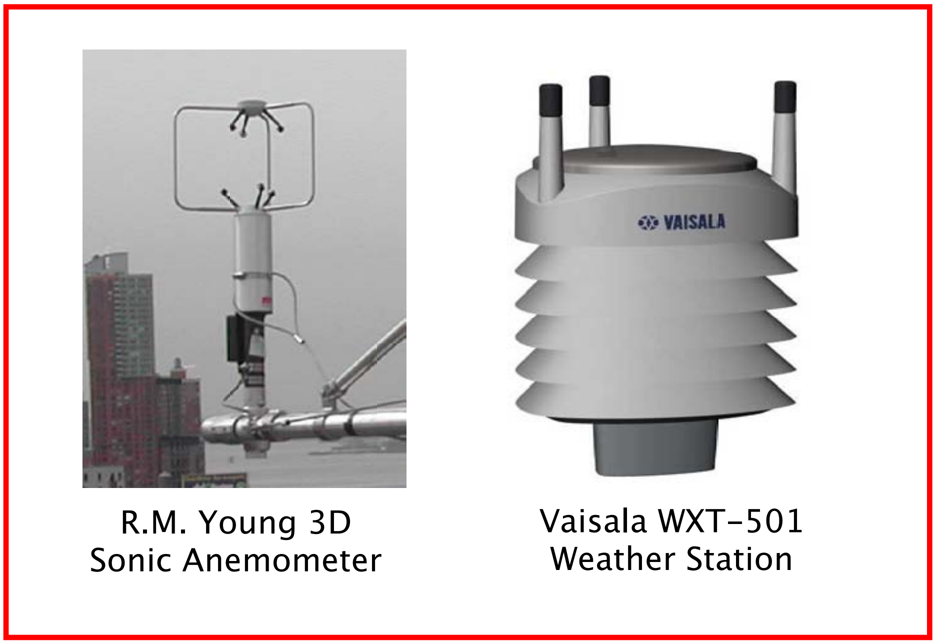
The MSG-05 data set has data from 27 different meteorological stations (Table 4). Each station was given a unique station identification code, the ID. Table 4 gives

Table 4: Stations in the MSG-05 data set. ELEV is ground elevation above sea level in m. HT is the height of the anemometer above ground in m. The various instruments are described in Reynolds (2005).

ID	TYPE	DESCRIPTION	LAT	LON	ELEV	HT
ccny	NOAA	CCNY Roof, NOAA GPS station	40.8167	-73.950	58	58
cpk	ASOS	Central park, NOAA ASOS	40.783	-73.967	39.6	25
eml	DCNet	Environ Meas Lab, 15th floor, roof	40.72842	-74.006617	5	82
ewr	ASOS	Newark Airport ASOS	40.717	-74.167	2.3	10
fok	ASOS	Westhampton Gabreski Airport	40.850	-72.633	20.4	10
hpn	ASOS	White Plains Westchester Co Airport	41.067	-73.700	115.5	10
hwv	ASOS	Shirley Brookhaven Airport	40.817	-72.867	25	10
isp	ASOS	Islip Long Island Macarthur Airport	40.800	-73.100	25.6	10
jfk	ASOS	New York J F Kennedy Int'l Airport	40.633	-73.767	3.4	10
lbr	DCNet	Lehman Brothers roof	40.76058	-73.98301	16.8	160
lga	ASOS	New York Laguardia Airport	40.783	-73.883	3.4	10
p26	MESO	Pier 26, Hudson River	40.72122	-74.01352	3	5.8
r1	ROOF	One Penn Plaza roof	40.75168	-73.99325	10.7	233
r2	ROOF	Two Penn Plaza roof	40.74999	-73.99219	8.8	133
r3a	ROOF	Farley P.O. met station	40.75157	-73.99632	10.4	34
r3b	SODAR	Farley Post Office (Sodar)	40.75156	-73.99632	10.4	24
r6	SBACK	One Peen Plaza, 7th floor setback	40.75073	-73.99146	10.7	34
r7	SBACK	One Penn, 12th fl setback	40.75080	-73.99154	10.7	50
s1	STREET	33rd St., NW corner of MSG	40.751283	-73.993736	10.7	3
s2	STREET	SW corner of MSG	40.750377	-73.994572	10.7	3
s3	STREET	SE corner of MSG	40.749727	-73.993177	10.7	3
s4	STREET	NE corner of MSG	40.750775	-73.992413	10.7	3
s5	STREET	34th St N of One Penn Plaza	40.751497	-73.992002	10	3
s6	SBACK	NY Hotel Overhang, Eighth Ave.	40.752472	-73.993827	10.7	5
s7	STREET	Street sta, SE corner 8th Ave and 30th St.	40.749330	-73.995447	10	3
sit1	MESO	Stevens Inst. Tech, Howe Center	40.74483	-74.02385	32	51.8
sit2	SODAR	Stevens Inst. Tech, Howe Center	40.74483	-74.02385	32	51.8

4 Instruments

This section provides a review of the instrumentation used by BNL during the MSG-05 experiment. Other scientific groups provided additional instrumentation and these will be described in separate report.



msg_anemometers
reynolds 051214

Figure 3: Anemometers used in the MSG-05 experiment. The R.M. Young model 81000 sonic anemometer measures the 3D wind vector at 10 Hz. The WXT510 uses a 2D sonic anemometer and produces a mean horizontal wind vector each three seconds. This weather station also measures air temperature, relative humidity, barometeric pressure, and rainfall.

4.1 Sonic anemometer

The three-dimensional sonic anemometer (3Dsonic) was the model 81000 manufactured by R.M. Young Co. was used for turbulence measurements in this project (figure 3). The instrument brochure with all specification is given in Appendix A. Table 5, below, provides key characteristics for the measurements.

Table 5: Specifications and Settings for 3D sonic anemometers during MSG-05

Internal sampling rate	160 Hz	Output sample rate	10 Hz
Output format	ASCII	Output variables	u, v, w, c, T_{sonic}
wind speed range	$0.01 - 40$ m s^{-1}	wind speed resolution	± 0.01 m s^{-1}
Valid wind elevation angles	$\pm 60°$		

We note that sonic anemometers are well suited for urban locations, especially at street level, where wind speeds have considerable vertical flow and where wind velocities can be quite small. However, a limitation in this type of instrument is that measurements become suspect with the elevation from horizontal exceeds $\pm 60°$. We will want to flag all 3Dsonic data where this limitation is exceeded.

The ASCII digital output from the 3Dsonic is collected by a laptop PC running a customized program called "ECCheck." ECCheck ingests each data line from the instrument and adds a time tag for the moment the record was received. It then writes a time stamped data record to a file. The data lines are position ordered as follows:

```
Field 1:  Columns  1- 3  Day-of-year          [day]
Field 2:  Columns  4-12  Time since midnight  [second]
Field 3:  Columns 13-15  Height, approx. MSL  [meter]
Field 4:  Columns 16-23  Wind from East       [m/s]
Field 5:  Columns 24-30  Wind from North      [m/s]
Field 6:  Columns 31-37  Wind from below      [m/s]
Field 7:  Columns 38-44  Speed of sound       [m/s]
Field 8:  Columns 45-52  Sonic temperature    [oC]
Field 9:  Columns 53-56  Status word          [bit mapped]

Sample:

087 35866.84 74    2.09  -0.15   1.55 338.88   11.82   0
087 35866.89 74    1.98  -0.30   1.45 338.86   11.78   0
087 35866.99 74    2.12  -0.61   1.17 338.86   11.78   0
087 35867.09 74    1.68  -0.56   1.13 338.70   11.54   0
087 35867.19 74    1.57  -0.39   0.99 338.70   11.54   0
087 35867.29 74    1.57  -0.52   1.07 338.66   11.45   0
```

The output from an RMY 81000 sonic anemometer is not guaranteed to be space delimited. Field melding can occur, for example when tranducers get wet. (The status word will also be nonzero when this happens.) We use fixed column width for parsing the input raw data lines.

The wind vector is given by fields 4–6 and is relative to the alignment of the sensor. Typically the sensor is aligned in an easy-to-use direction such as the edge of the a building roof or perpindicular to a street. Then the winds are converted to true North (u, v, w) during processing.

Raw file names are written in the format

```
ID$YYYYMMDD.dat
where
  ID = Laptop ID (must be coordinated with the data set)
  YYYY = year, e.g. 2005
  MM = month, e.g. 10
  DD = day of the month, e.g. 03

example: UDP09$20050310.dat
```

Date and time stamping are done by the data collection computer. Occasionally network delays and computer interrupts cause missed lines or a delay in the timestamp. These glitches are rare and easily removed during the data processing.

4.2 Vaisala WXT510 weather station

The Vaisala Weather Transmitter, WXT510, is a compact and lightweight multi-sensor instrument that measures the most essential weather parameters (Figure 3). It is a configurable product that can measure wind speed, direction, liquid precipitation, barometric pressure, temperature and relative humidity in one package. Appendix B provides an overall review of the WXT510, and specific settings for MSG-05 are given below.

The WXT510 connects to a laptop PC running an application called DataXbar. This program was developed at BNL for the express purpose of logging ASCII strings produced by digital instruments. DataXbar takes each

Table 6: Specifications and Settings for Vaisala WXT510 weather transmitter.

Internal sampling rate	?? Hz	Output sample rate	3 sec
Output format	ASCII	Output variables	S, D, T_a, RH, P, R_i
wind speed	$0.1 - 60 \pm 0.1$ m s^{-1}	wind direction	$\pm 1°$

record from the instrument as a string and prepends a date-time string before storing into memory. A data line from the WXT510, as setup for the experiment, is shown below:

```
2005-03-10,08:03:59,0R0,Dm=116D,Sm=4.5M,Ta=-4.8C,Ua=42.9P,Pa=1008.5H,Ri=0.0M,
Th=-2.3C,Vh=10.8W,Vs=8.5V,Vr=3.529V
```

The line here longer than the page and has been shown in sections. The different fields in the raw line are as follows:

`2005-03-10`	Instrument clock date (laptop)	
`08:03:59`	Instrument time (laptop)	
`DM=116D`	Vector mean wind direction	deg
`Sm=4.5M`	Vector mean speed	m s^{-1}
`Ta=-4.8C`	Air temperature	°C
`Ua=42.9P`	Relative humidity	%RH
`Pa=1008.5H`	Barometric pressure	hPa
`Ri=0.0M`	Rain intensity	mm/hr
`Th=-2.3C`	Heater temperature	°C
`Vh=10.8W`	Heater voltage	volts
`Vs=8.5V`	Input voltage	volts
`Vr=3.529V`	Reference voltage	volts

The date and time here are produced by the data acquisition computer and are prepended by DataXbar program.

4.3 Tripod towers and setback frames

Two types of tripod towers were used in MSG-05 (figure 4). Rooftop deployments used a 6-m tower made from schedule 40 aluminum pipe and coupler fittings. The design allows for rapid installation yet can withstand winds greater than 60 m s^{-1}.

The same design was modified to produce 3-m tripod towers for the street stations.

4.4 miniSodar

Sodar (sonic detection and ranging) systems are used to remotely measure the vertical turbulence structure and the wind profile of the lower layer of the atmosphere. Sodar systems are like radar (radio detection and ranging) systems except that sound waves rather than radio waves are used for detection. Other names used for sodar systems include sounder, echosounder and acoustic radar. A more familiar related term may be sonar, which stands for sound navigation ranging. Sonar systems detect the presence and location of objects submerged in water (e.g., submarines) by means of sonic waves reflected back to the source. Sodar systems are similar, except the medium is air instead of water, and reflection is due to the scattering of sound by atmospheric turbulence.

Sodars operate on the principle of acoustic backscattering. An electronic sound driver is used to generate an acoustic pulse into the atmosphere with a frequency typically between 1 and 5 KHz. The duration of each pulse is usually between 50 and 300 ms. As the sound wave propagates through the atmosphere, a small fraction of its energy is scattered back to the surface by small scale temperature inhomogeneities whose scale is similar to that of the wavelength of the acoustic pulse (Gaynor, 1977). The backscattered signal is amplified and the received time series is subdivided into time blocks, called range gates, each representing a discrete layer in the atmosphere. Any number of algorithms are employed to determine the mean frequency of the backscattered signal (Neff and Coulter, 1986).

The Doppler shift, that is to say the difference between the transmitted frequency and the backscattered frequency, is directly proportional to the radial wind velocity along the acoustic beam axis. Determination of the total wind vector requires a minimum of three independent radial wind velocities. The miniSodar uses three narrow beams, one vertical and two at an angle of, typically, 6° from vertical. Computation of the three dimensional wind vector at the range gate height relies on an assumption that the wind field is horizontally homogenious, or varies in space very gradually since the radial wind vectors are separated in space. (At $h = 100\,\mathrm{m}$, the separation will be 20 m).

Sodars which use acoustic frequencies less than 2 KHz generally have a maximum sounding range of 1 to 2 km (Clifford et al., 1994). The range of a sodar using acoustic pulses greater than 2 KHz drops off dramatically with increasing frequency because of the effects of molecular attenuation. A sodar with a transmit frequency of 4 to 5 KHz has a maximum range of about 200 to 300 m in quiet environments. Urban environments are notoriously noisy and limit the usefulness of sodars. However, most environmental noise tends to exhibit frequencies less than 2 KHz and its spectrum falls off sharply as frequency increases. The challenge is attempting to find a balance which will maximize sodar range and minimize noise interference.

Sodars for atmospheric research were first developed in Australia in the late 1960's (McAllister et al. (1968); Little (1969); Beran (1970); Reynolds (1970)). The sodar became a commercial product in 1978 Schwieson (1986). The miniSODAR, the instrument used in this study, was developed by AeroVironment Inc. in the late 1980's to measure wind profiles in helicopter landing areas where noise levels were extreme. It was made commercially available in 1994 and has been deployed in situations where winds within the lowest 200 m are needed and ambient noise in the lower frequency range (1000–2000 Hz) is high. It was determined that the optimum frequencies to operate SODAR in these conditions was near 4500 Hz. The same conclusion was reached by Crescenti and Baxter (1998) and Crescenti (1998) for the urban environment where automobiles and HVAC systems can add considerable ambient noise.

The following table lists the specifications for the miniSodar.

Table 7: Settings for miniSodars used during MSG-05

Maximum Sampling Altitude	200 m	Power input (electrical)	30 W
Minimum sampling Altitude	15 m	Power output (acoustic avg)	40 W
Height Resolution	10 m	Voltage	120/220 VAC
Transmit frequency	4500 Hz	Weight	255 lbs
Averaging interval	60 min	Antenna ht	1.2 m
Wind speed range	0–35 $\mathrm{m\,s^{-1}}$	Antenna Width	1.2 m
Wind speed accuracy	$< 0.5\ \mathrm{m\,s^{-1}}$	Antenna length	1.5 m
Wind direction accuracy	$< 5°$	Total ht with collar	2.1 m
Beam width	??°	Beam zenith angles	6°

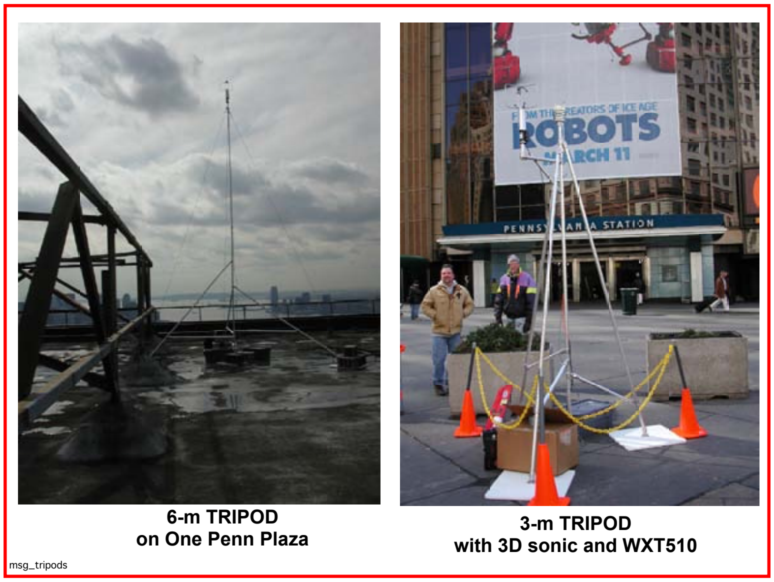


Figure 4: Tripods used in the MSG-05 experiment. The 6-m tripod is free standing and capable of withstanding 60 m/s winds. The 3-m tripod shown here supports both the 3Dsonic anemometer and the WXT510 weather transmitter.

Figure 5: The setback station S6 on the New Yorker Hotel Overhang.

Figure 6: A miniSodar on the Farley Post Office roof during the MSG-05 experiment. In the background, from left to right, are One Penn Plaza, Madison Square Garden, and Two Penn Plaza.

4.5 External Instrumentation

4.5.1 CCNY

The NOAA-CREST weather station, located on the roof of the Science Building, began operation on 12 December, 2003. The station's sensors collect data each second and compute one-minute averages. The information is relayed to the Engineering building via the campus internet. Archived data is available on the NOAA-CREST web site. Data includes wind speed, direction and their vectors; air, dew point, wet bulb, heat index and wind chill temperatures; relative humidity; air pressure; rain; plant trans-evaporation and solar flux. More information on this site can be found at `http://icerd.engr.ccny.cuny.edu/noaa/wc/`.

Figure 7: The CCNY weather station, east view.

4.5.2 NOAA ASOS

The Automated Surface Observing Systems (ASOS) program is a joint effort of the National Weather Service (NWS), the Federal Aviation Administration (FAA), and the Department of Defense (DOD). The ASOS systems serves as the nation's primary surface weather observing network. ASOS is designed to support weather forecast activities and aviation operations and, at the same time, support the needs of the meteorological, hydrological, and climatological research communities.
Reports basic weather elements:

- Sky condition: cloud height and amount (clear, scattered, broken, overcast) up to 12,000 feet
- Visibility: (to at least 10 statute miles)
- Basic present weather information: type and intensity for rain, snow, and freezing rain
- Obstructions to vision: fog, haze
- Pressure: sea-level pressure, altimeter setting
- Ambient temperature, dew point temperature
- Wind direction, speed and character (gusts, squalls)
- Precipitation accumulation
- Selected significant remarks including- variable cloud height, variable visibility, precipitation beginning/ending times, rapid pressure changes, pressure change tendency, wind shift, peak wind.

More information on this site can be found at `http://www.nws.noaa.gov/asos/`.

Figure 8: A typical ASOS weather station

4.5.3 NOAA DCNet

4.5.4 Stevens Institute of Technology

The New York Harbor Observing and Prediction System (NYHOPS) was established to permit an assessment of ocean, weather, environmental, and vessel traffic conditions throughout the New York Harbor region. The system is designed to provide a knowledge of meteorological and oceanographic conditions both in real-time and forecasted out to 48 hours in the Hudson River, the East River, NY/NJ Estuary, Raritan Bay, Long

Island Sound and the coastal waters of New Jersey. In this web site you will see graphic images of water level, surface and bottom temperature, surface and bottom salinity, surface and bottom currents and NOAA meteorological predictions. Real time data is only available in the NY/NJ Estuary. For more information see `http://hudson.dl.stevens-tech.edu/NYHOPS/`

5 MSG Deployment Procedures

Two main issues are involved in each deployment. (1) The tripods must be vertical to $< \pm 0.5°$, and (2) The anemometers must be aligned in a known direction so that measurements can be reduced to a true north alignment.

5.1 Roof wind station deployment

The alignment is towards the northward roof edge. By northward edge we mean that a perpindicular line from the station to the roof edge lies in an approximate northerly direction. This alignment is easy to do during the installation. The orientation of the roof edge can be found to good accuracy using GIS or survey data.

5.2 Setback station deployment

The lubber line of the instrument faces perpindicular to the face of the setback so that relative (u, v, w) are aligned up the street to the right, away from the building face, and upwards. Thus, $\pm u$ is flow up or down the street, $\pm v$ is flow away from or into the face of the building. As above, when we know the orientation of the building face we can transform the measurements to a true north coordinate system.

5.3 Street wind station deployment

Street stations are aligned either perpindicular to the street or along the Avenues. The true north orientation is computed during data processing.

5.4 Sodar Installation and Operation

The miniSodar has a North reference direction (the "lubber line" in nautical terms) and this defines the computed wind vector, (u, v, w) in vector wind convention, the direction toward which the wind is blowing. In an urban environment on a rooftop, it is difficult to determine the exact direction of true North. Instead we align the sodar to be perpendicular to the northern roof edge. The exact alignment of the building, and thus its northern roof edge, can be determined from GIS data bases or from known building surveys. The sodar alignment is recorded and the wind direction is corrected during the data processing.

7 Data Processing

7.3 WXT510 Weather Station Processing

The WXT provides spd, dir, ta, rh, p, and rain each 3 seconds.

Each 3sec record is saved as a raw file.

Each 3s spd/dir pair are converted to u/v (no coord xform).

Each dir is converted to unit vector components x/y.

u, v, x, y, ta, rh, p are summed over the avg interval (5 or 10 min).

Also the squares are summed for stdev calculations.

Averages U, V, X, Y, TA, RH, P are computed.

Stdev's of all are computed from sums and sums of squares.

U/V are rotated to the true N frame of reference.

S/D are computed from U/V.

X/Y are used to compute sigmatheta via Yamartino.

7.4 miniSodar Data Processing

The miniSodar software is called "SodarPRO" a two(??) different versions were used during the 15month experiment. SodarPRO parameter set were as follows:

The AV system produces an ascii raw data file each time step (1 minute). The files contains a matrix of range heights versus computed variables for that range. The following variables are extracted verbatim from the raw AV data file:

> yyyy MM dd hh mm ss d_sec z wspd wdir Av_u sig_u snr_u
> Av_v sig_v snr_v Av_w sig_w snr_w

where z is the measurement height and represents the center of the range gate in meters; [Av_u sig_u snr_u] are the average X wind speed over the averaging perod, the standard deviation of the U (East) wind vector, and the mean signaltonoise ration during the averaging time. The same applies to the V (North) vector and the W (up) vector.

The sample time (*yyyy MM dd hh mm ss*) is the time at the end of the averaging period and is the time reported in the AV raw file with no correction for time zone.

The AeroVoronment SODAR program, "SodarPRO," processes incoming acoustic data and produces raw data files. At the end of each averaging period, one minute for the NYC experiment, a data block is written to an ascii raw data file. An example of one data block is given in Appendix C. When the signal-to-noise ration, "snr", falls too low, *i.e.* the measurements are given a missing value of 99.99 for floating point numbers and 9999 for integers. The wind components, (u, v, w), along with the standard deviation and the average snr for each component are listed. The components are combined to compute an average wind speed and direction for the one minute averaging period.

However, SodarPRO only tags the worst of the data. Non-missing raw data from any height interval is still repleat with noise problems and it is the challenge of the post-processing software to find and remove the sporadic noise contamination. Post processing software is aimed at producing the best possible time series of horizontal and vertical winds for any given height. Data is thus separated

Program `read_sodar_dat.pl` reads the ascii data file from the AV program and extracts a specific height range gate. Extraction is verbatim, e.g. no corrections are made to the raw AV output data. Specific range gate heights

Detecting and Correcting Sodar Errors

Techniques for removal of sporadic errors have been provided by Fleming (Fleming and Hill, 1982) and Taylor(Taylor, 1982). The *Chauvenet's Criterion* method was used to reject outlying points. In each averaging interval a set of scalar measurements can be represented by $x = (x_0, x_1, x_2, \ldots x_{n-1})$. The mean, $\overline{x}$ and standard deviation, σ_x are computed. The maximum value is used to compute the relative size of the maximum outlier: $t = (x_{max} - \overline{x})/\sigma_x)$ and this is used in the error function to estimate the probability of a single point being this far away from the mean.

$$P(x >= t) = \operatorname{erfc}(t/\sqrt{2}) = \frac{2}{\sqrt{\pi}} \int_x^\infty e^{-t^2/2}\, dt$$

If, for n points, the product $n\,P(x >= t) <= 0.5$, the datum is rejected. If a point is rejected, the process is repeated at least one more time.

Noise in the SODAR data occurs often as sporadic bursts which are effectively removed by the Chauvenet's criterion, described above. Occasionally an averaging time block will be primarily "bad" data and in this case chauvenet's criterion fails to work properly because it will remove the good data points which are in a minority. An *ad hoc* method was developed from trial and error. When an averaged block is dominated by noise, the resulting value of S_v, the vector mean speed tends to jump significantly from surrounding good data. An example time series might be $S_v = \{\ldots, 1.45, 1.96, 2.21, 22.34, 15.55, 1.45, 1.98, \ldots\}$.

The final cleaning process compares the current value of S_v with the previous value. If the time gap since the last good block is less than 2 hours and if the difference between $S_v(\text{now}) - S_v(\text{last}) < 10\ \text{m}\,\text{s}^{-1}$, then the block is recorded, otherwise it is rejected. This last procedure removes almost all of the sporadic periods of noise.

Table 8: Results from the three-step cleaning process for SODAR wind time series from different levels above the roof. The SODAR deployment period was 471.4 days and during this time the data recovery was 94.1%. Outtages were due to software crashes and a power failure. Of the recovered data, the number of bad winds, N_{error}, varied from 3% at 20 m to 18% data loss at 60 m.

Z	N	N_{error}	% bad
20	42596	1105	3
40	42596	3817	9
60	42596	7767	18

Double checking and reality checks.
Becuase of the considerable difference between the wind roses from the anemometer and the sodar (Fig. **??**) the programs and the output files were double checked in a step-by-step fashion. This was done during the initial development of the code, but was repeated with great care as a caution. After verifying the software, comparison plots of sodar and anemometer data were made for short time blocks throughout the time series.

The Comparison Wind Station The NOAA Air Resources Laboratory (ARL) deployed a meteorological station on the EML building in February 2003 as a permanent installation.

8 Quality Assurance and Data Uncertainty

Precaution and cross-checking have been practiced to assure that the data are of good quality. The following specific steps have been followed:

1. All instrumentations was factory calibrated before the experiment. During the deployments, all instrumentation serial numbers are recorded and we make sure each instrument at each station is exactly the same for each IOP.
2. Two street stations had dual instrumentation, a 3DSonic anemometer and a Vaisala WXT510 2Dsonic weather station. Data from these two instruments, involviing independent data collection and data processing, compare very well. The comparison is discussed below.
3. After the experiment, all instruments were taken to the BNL meteorological field and operated together for an extended time. This intercomparison had excellent results and further confiemed the veracity of the experiment measurements. (Also discussed below.)
4. Model validation. The experiment measurements agree well with the various CFD model results. Of course the idea of the measurements is to validate the models and so it is disingenuous to reverse the comparison. Nevertheless, approximate agreement suggests there were no gross errors such as might occur if the wind direction conventions (blowing from or to) are wrong.
5. We rely on a process of user feedback followed by a new release of data. Errors, typos, or processing errors in the archive data set are noted and on a routine basis a new release of the data will be made. This document will carry a summary sheet which outlines all changes in the data set for each release.

8.1 3D sonic and WXT comparisons at two street stations

Two street stations, S1 and S4, were configured with two different types of wind instruments. The RMY 3D sonic anemometer and the new WXT510 2D sonic digital weather station were operated side-by-side as shown in Figure 4. Each of these instruments was aligned to relative north independently from the other. This was considered a good opportunity to evaluate the performance of the new WXT instruments against the widely used RMY 3dsonic anemometers.

The horizontal winds measured by the 3D sonic anemometer and the WXT weather station are compared in Figures 9 and 10. All data shown here come from the 300 sec vector averaged wind time series. The 3dsonic sampled at 10 Hz so 3000 points were averaged. The WXT510 sampled at about 6 Hz but produced averaged output lines each 3 sec (This is the minimal record interval possible for the WXT.) so only about 100 points were included in the 300-sec average.

A group of four graphs are show here for each IOP and for each dual station. The upper left panels in each group shows the inverse relationship between σ_θ and windspeed v. However, the mean difference and standard deviation in the difference $(\sigma_{\theta R} - \sigma_{\theta W})$ are only 2.3° and 2.1° respectively.

The upper right panel compares the variability in the wind direction difference, $\theta_R - \theta_W$, as a function of wind speed. When $v < 0.5\ \mathrm{m\,s^{-1}}$, the differences become quite large. This might be expected. Note that the wind vectors we consider here are vector averages and it is possible to have a very small mean wind speed in a strongly turbulent situation.

The lower left panel is a histogram of the vector mean wind speed difference and the lower right panel shows a histogram of the direction differences. Because the direction difference is so noisy at low wind speeds, we show data here only when $V > 0.5\ \mathrm{m\,s^{-1}}$. The comparisons for the two stations in the two IOPs are as follows

	IOP1		IOP2	
	S1	S2	S1	S2
Δv	-0.03	-0.01	0.03	-0.18
$\sigma_{\Delta v}$	0.08	0.07	0.05	0.11
ΔD	0.22	-3.64	2.01	0.60
$\sigma_{\Delta D}$	1.31	3.85	0.91	1.08

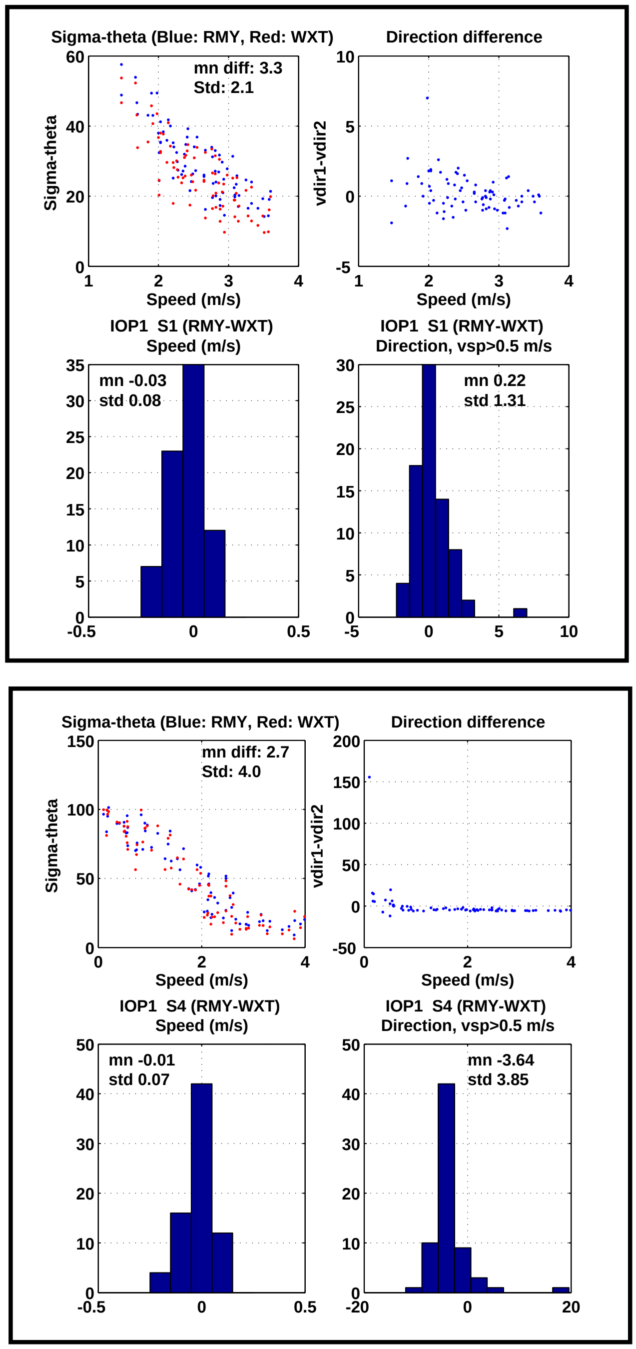


Figure 9: Comparison of winds measured by RMY3d and WXT510 during IOP1.

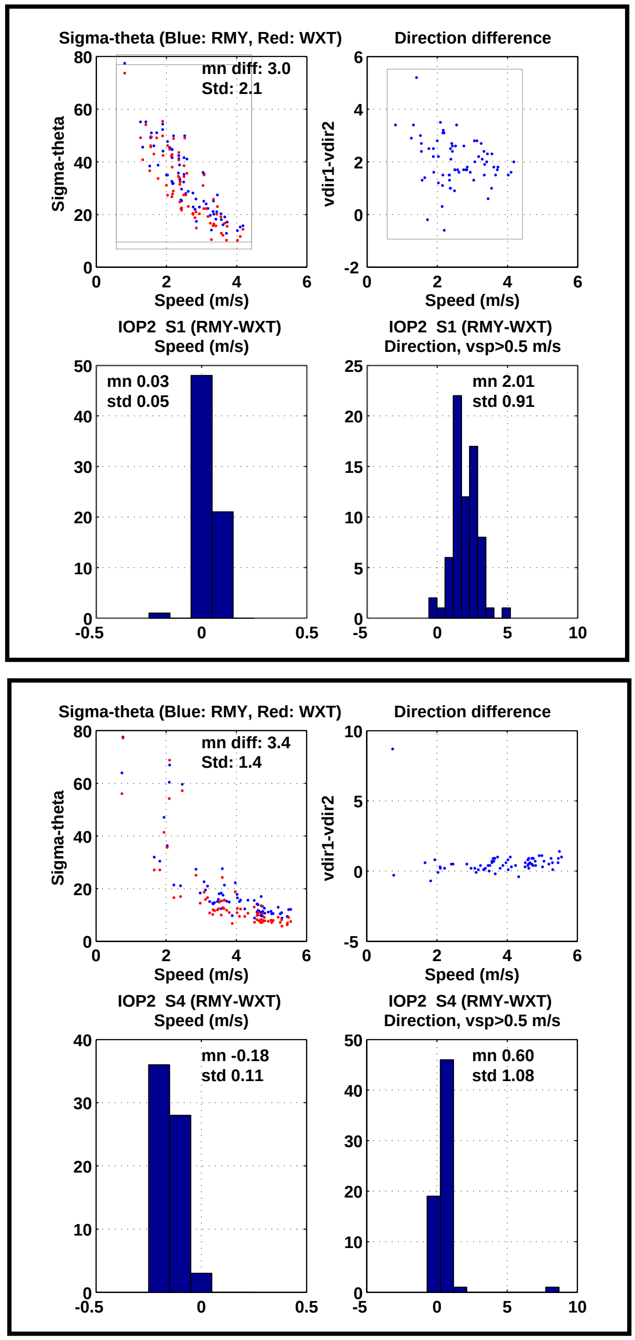


Figure 10: Compare RMY3d and WXT510 during IOP2.

8.2 Post Experiment Field Intercomparisons

After the experiment, all instrumentation was brought to the BNL meteorological field for a field intercomparison. Stations S1, S2, S3, S4, S5, and S7 were intercompared by setting them up in the same location in the middle of the large open (approx 4 hectare) field where the BNL meteorological tower is located. The tripods were spaced about 10 m apart in a N-S alignment. In this way we could have good exposure as long as the wind was not in the sectors of 340–20° and 160–200°. The instruments were operated for three days. The vector mean wind speed and directions are shown in Figure 11.

From the beginning of the intercomparison to about 16hr on the next day winds were consistent, strong, and from about 300°. After that a period of very low, irratic, and northerly winds ensued. The latter period was not used for the intercomparison because sheltering of the tripods caused erratic and noisy conditions.

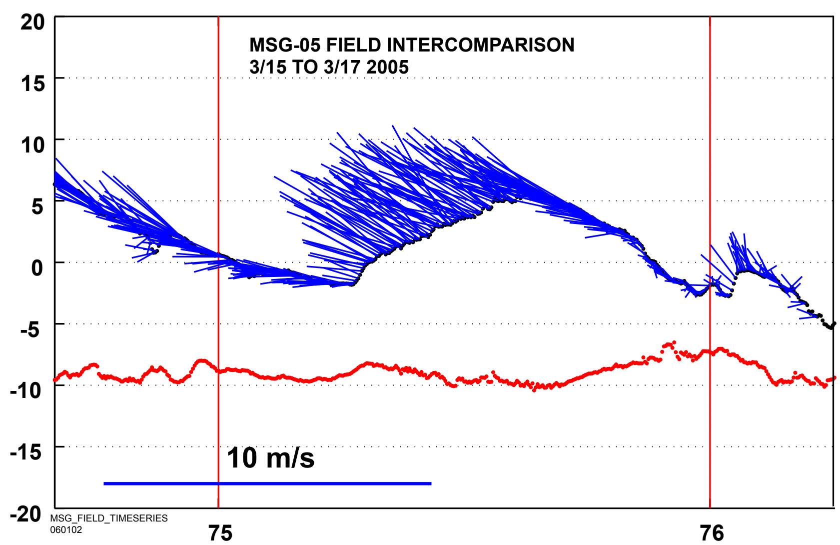


Figure 11: Mean wind speeds during the field intercomparison. shown are plots of air temperature and dew point (red). Superimposed on the temperature plot are wind vectors. The sticks are oriented towards the wind meteorological direction. The beginning 24 hours of the comparison had NW winds.

Table 9: Results from the field intercomparison of the street stations. Street stations included in this study are S1, S2, S3, S4, S5, and S7. A suffix 'r' signifies an RMY 3D anemometer and a suffix 'w' signifies a WXT510.

		s1r	s1w	s2w	s3w	s4r	s4w	s5r	s7r
spd	mn	-0.01	-0.06	-0.00	-0.14	-0.09	-0.16	-0.02	0.48
	std	0.09	0.07	0.05	0.04	0.07	0.07	0.07	0.24
vsp	mn	0.07	0.02	0.08	-0.07	-0.03	-0.08	0.03	0.58
	std	0.07	0.06	0.04	0.05	0.06	0.08	0.04	0.29
vdir	mn	-0.24	-1.29	4.65	-0.62	-0.78	-4.61	0.90	13.57
	std	2.86	3.04	1.70	16.14	3.06	12.04	2.00	14.07
sigth	mn	0.29	0.20	-1.27	1.30	2.05	1.38	1.90	-5.85
	std	1.93	2.53	1.41	2.85	1.90	3.45	1.77	7.92

Notes: The RMY3D at S7 showed poor behavior. The alignment in the field was unusually large and there seems to be a high noise in the measurements. The overall effect in mean speed and σ_θ, while large, are still usable.

8.3 Sodar Data Evaluation

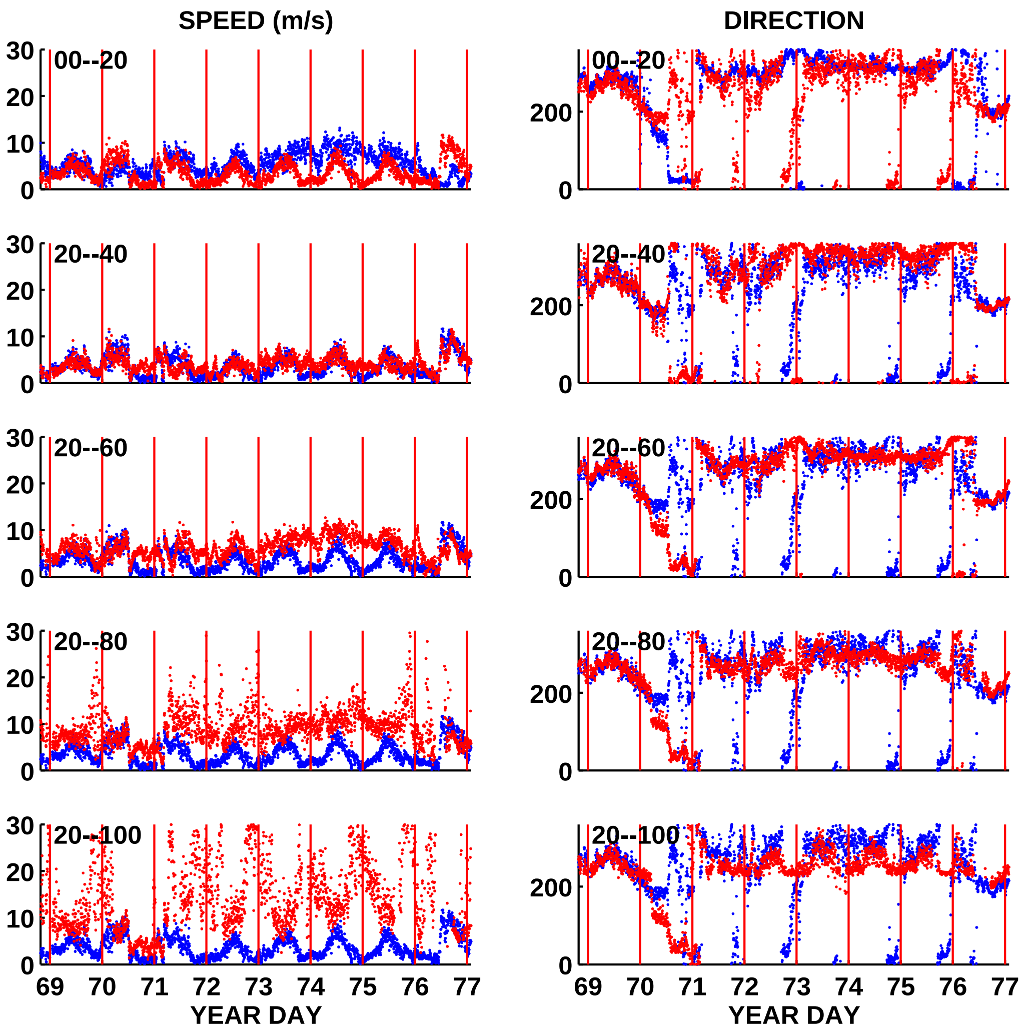


Figure 12: Sodar and met data from SIT. The IOPs took place on the mornings of Julian days 69 and 73. The wind speeds and directions measured by the sodar show a marked change at heights above about 60 m. Wind speeds became quite strong while directions were consistent throughout. There is some question whether this is an artifact of noise or is real.

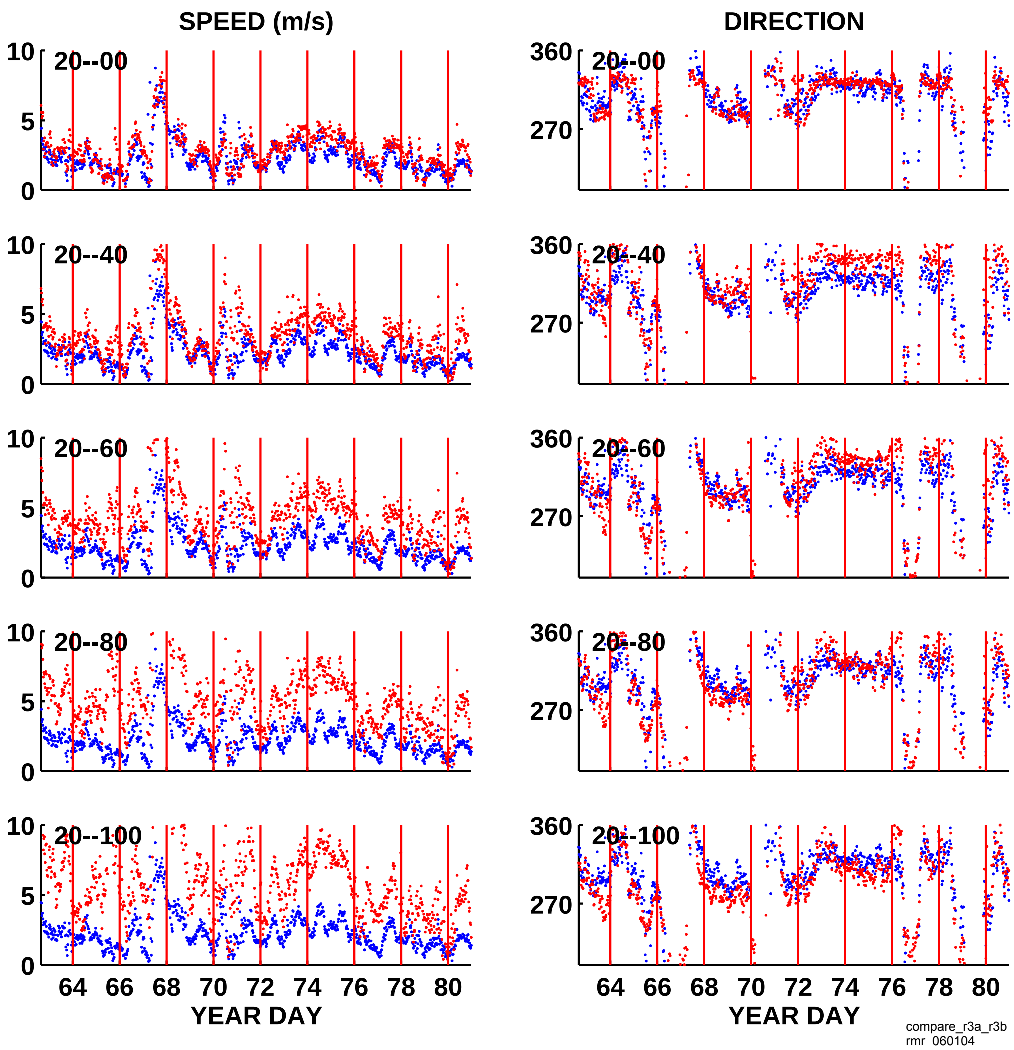


Figure 13: Sodar and met data from Farley Post Office. The IOPs took place on the mornings of Julian days 69 and 73. The wind speeds and directions measured by the sodar show a marked change at heights above about 60 m. These results are much better behaved than the SIT data in figure 12.

The MSG05 Meteorological Team

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Scott Smith Instrument fabrication, street station logistics.

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A R. M. Young Model 81000 3D Sonic Anemometer

YOUNG Model 81000 **Ultrasonic Anemometer**

The YOUNG Model 81000 Ultrasonic Anemometer is a 3-axis, no moving parts wind sensor. It is perfectly suited for applications requiring fast response, high resolution and three-dimensional wind measurement.

The sensor features durable, corrosion-resistant construction with 3 opposing pairs of ultrasonic transducers supported by stainless steel members. The transducers are arranged so that measurements are made through a common volume. A fast, 160 Hz internal sampling rate ensures superior measurement resolution. Output rates from 4 to 32 Hz may be selected. Each 81000 is individually wind-tunnel tested and calibrated to compensate for wind shadow effects of the support structure.

Model 81000 features four voltage ouput channels. Serial RS-232 and RS-485 outputs are available as well. For applications requiring synchronized analog measurements, **Model 81000V** includes four voltage input channels instead of voltage outputs. Wind, sonic temperature and voltage input data are transmitted serially. For each model, a variety of preset or custom output format options may be selected by the user.

Both models install on standard 1 inch pipe. Wiring connections are housed in a convenient weatherproof junction box.

Ordering Information

Ordering Information	MODEL
ULTRASONIC ANEMOMETER- *VOLTAGE & SERIAL OUTPUTS*	**81000**
ULTRASONIC ANEMOMETER- *VOLTAGE INPUTS, SERIAL OUTPUTS ONLY*	**81000V**

Specifications

Wind Speed: 0 to 40 m/s (0 to 90 mph)
Resolution: 0.01 m/s
Threshold: 0.01 m/s
Accuracy: ± 1% rms ±0.05 m/s (0 to 30 m/s)
± 3% rms (30 to 40 m/s)

Wind Direction: 0 to 360 degrees
Elevation Range: ± 60 degrees
Resolution: 0.1 degree
Accuracy: ± 2 degrees (1 to 30 m/s)
± 5 degrees (30 to 40 m/s)

Speed of Sound: 300 to 360 m/s
Resolution: 0.01 m/s
Accuracy: ± 0.1% rms ± 0.05 m/s (0 to 30 m/s)

Sonic Temperature: -50 to +50 °C
Resolution: 0.01 °C
Accuracy: ± 2 °C (0 to 30 m/s)

Serial Output:
RS-232 or RS-485
1200 to 38400 baud
4 to 32 Hz (user-selected)
User Programmable ASCII output configuration (select from U, V, W, Speed of sound, Sonic temperature, 2D speed, 3D speed, Azimuth, Elevation)
Preset outputs:
NMEA- Marine Standard
RMYT- Young Wind Tracker
Units: m/s, cm/s, MPH, Knots, Km/hr

Analog Voltage Outputs (81000):
4 voltage outputs, 0 to 5000 mV
(select from U, V, W, Sonic temperature or Speed, Azimuth, Elevation, Sonic temperature)

Voltage Input (81000V):
Range: 0 to 5000 mV, V1 & V2
0 to 1000 mV, V3 & V4
Resolution: 1 part in 4000
Accuracy: ± 0.1% of full scale

Power Requirement:
12 to 24 VDC, 110 mA

Operating Temperature:
-50 to +50 °C

Dimensions:
56cm high x 17cm radius (3 support arms)
Weight: 1.7 kg (3.8 lb)
Shipping Weight: 4.5 kg (10 lb)

CE *Complies with applicable CE Directives*

YOUNG
R.M. YOUNG COMPANY
2801 Aero Park Drive
Traverse City, Michigan 49686 USA
TEL: (231) 946-3980 FAX: (231) 946-4772
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Web Site: www.youngusa.com

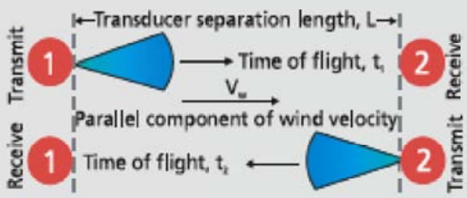
B WXT510

WXT510 WEATHER MULTI-SENSOR

Technical Data

Operating Principle

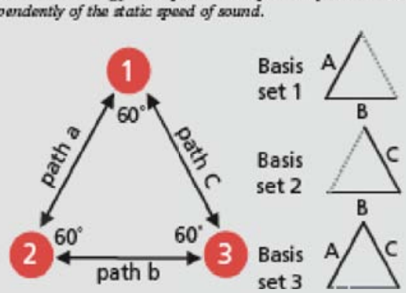
Vaisala WINDCAP® Sensor



For static speed of sound V_s: $\frac{1}{t_1} = \frac{V_s + V_w}{L}$ and $\frac{1}{t_2} = \frac{V_s - V_w}{L}$

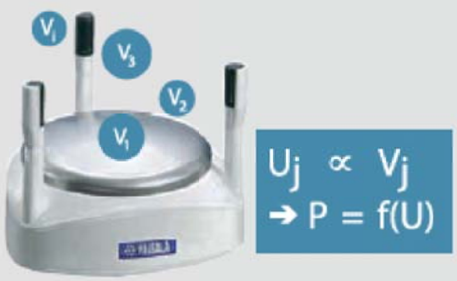
Combine to remove V_s: $V_w = \frac{L}{2}\left(\frac{1}{t_1} - \frac{1}{t_2}\right)$
Solve for V_w

Time-of-flight for a sonic impulse from the transmit transducer to the receive transducer is determined for both directions. Simple algebra allows solving for the parallel component of wind velocity independently of the static speed of sound.



The equilateral triangle configuration of the three transducers provides three possible sets of basis vectors. The combinations yield bi-directional measurements on the paths labeled A, B and C. These measurements are used to determine the wind velocity components parallel to each of the three paths.

Vaisala RAINCAP® Sensor



The precipitation sensor detects the impact of individual raindrops. The voltage signals U_j resulting from the impacts are proportional to the volume of the drops V_j and therefore, the signal of each drop can be directly converted to accumulated precipitation P.

Wind

Wind speed	
Range	0..60 m/s
Response time	0.25 s
Available variables	average, maximum and minimum
Accuracy	± 0.3 m/s or ±2% whichever is greater
Output resolution	0.1 m/s (km/h, mph, knots)
Units available	m/s, km/h, mph, knots
Wind direction	
Azimuth	0..360°
Response time	250 ms
Available variables	Average, maximum and minimum
Accuracy	± 2°
Output resolution	1°
Measurement frame	
Averaging time	1...600 s (= 10 min), at one second steps on the basis of 0.25 second samples
Update interval	1...3 600 s (= 60 min), at one second steps

Liquid Precipitation

Rainfall	cumulative accumulation after latest automatic or manual reset
Collecting area	60 cm²
Output resolution	0.01 mm (0.001 in)
Accuracy	5% *
Units available	mm, in
Rain duration	counting each ten second increment whenever droplet detected
Output resolution	10 s
Rain intensity	one minute running average in ten second steps
Range	0..200 mm/h (broader range with reduced accuracy)
Output resolution	0.1 mm/h (0.01 in/h)
Units available	mm/h, in/h
Hail	cumulative amount of hits against collecting surface
Output resolution	0.1 hits/cm² (1 hits/in²)
Units avaiable	hits/cm², hits/in², hits
Hail duration	counting each ten second increment whenever hailstone detected
Output resolution	10 s
Hail intensity	one minute running average in ten second steps
Output resolution	0.1 hits/cm²h (1 hits/in²h)
Units available	hits/cm²h, hits/in²h, hits/h

* Due to the nature of the phenomenon, deviations caused by spatial variations may exist in precipitation readings, especially in short time scale. The accuracy specification does not include possible wind induced error.

PTU module = Barometric Pressure, Air Temperature and Relative Humidity

Barometric Pressure

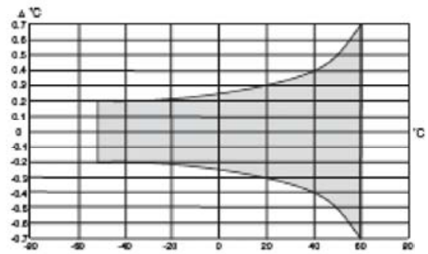
Range	600..1 100 hPa
Accuracy	±0.5 hPa at 0..+30 °C (+32..+86 °F)
	±1 hPa at -52..+60 °C (-60..+140 °F)

Technical Data, Dimensions

Output resolution	0.1 hPa, 10 Pa, 0.0001 bar, 0.1 mmHg, 0.01 inHg
Units available	hPa, Pa, bar, mmHg, inHg

Air Temperature

Range	-52 ... +60 °C (-60...+140 °F)
Accuracy (for sensor element) at +20 °C (+68 °F)	±0.3 °C (±0.5 °F)
Accuracy over temperature range (see graph)	



Output resolution	0.1 °C (0.1 °F)
Units available	°C, °F

Relative Humidity

Range	0...100 %RH
Accuracy	±3 %RH within 0...90 %RH ±5 %RH within 90...100 %RH
Output resolution	0.1 %RH

PTU Update Interval

Update interval	5...3 600 s (= 60 min), at one second steps

General

Self-diagnostic	separate supervision message, unit/status fields to validate measurement quality
Start-up	automatic, < 10 seconds from power on to the first valid output
Communication protocols	SDI-12 v1.3, ASCII automatic & polled, NMEA-0183 v3.0 with query option
Port H/W	SDI-12, RS-232, RS-485, RS-422
Baud rate	1 200, 2400...115 200
Operating temperature	-52...+60 °C (-60...+140 °F)
Storage temperature	-60...+70 °C (-76...+158 °F)
Operating humidity	0...100 %RH
Dimensions	
Height	240 mm (9.4 in)
Diameter	120 mm (4.7 in)
Weight	650 g (1.43 lbs)

Power Supply

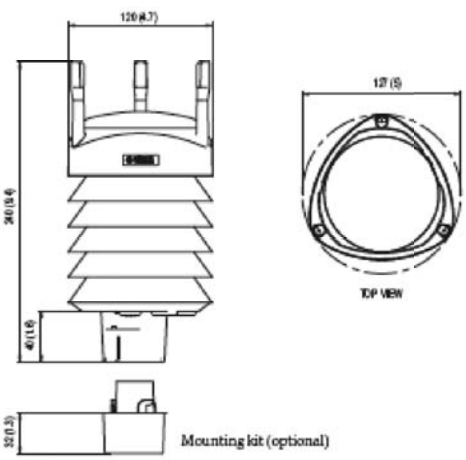
Input Voltage	5...30 VDC
Power consumption on average	
minimum	0.07 mA @ 12 VDC (in SDI-12 mode)
maximum	13 mA @ 30 VDC (with continuous measurement of all parameters)
typical	3 mA @ 12 VDC (with default measuring intervals)
Heating voltage	options: DC, AC, full wave rectified AC
recommended ranges	12 VDC ±20%, 1.1 A max. 24 VDC ±20%, 0.6 A max. 68 V_{p-p} ±20% (AC), 0.6 A_{rms} max. 34 V_p ±20% (f/w rect. AC), 0.6 A_{rms} max.
absolute max	30 VDC 84 V_{p-p} (AC) 42 V_p (f/w rect. AC)

Electromagnetic compatibility

Complies with EMC standard: EN61326-1:1997 + Am1:1998 + Am2:2001; Generic Environment.

Dimensions

Dimensions in mm (inches).



CE

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Please look for other locations at www.vaisala.com.

VAISALA
www.vaisala.com

Ref. B210417en 2004-11

C SODAR Raw Data Block

```
NYC0006  08/09/2003 00:11:03 TO 08/09/2003 00:12:00 VR3.09  4500    800    100     50     10      0      0
60 5 0 7 -120 0 10 15 64 960 6 5 5 -800 800 -800 800 -400 400 1 10 6 300 68 1 39 0 0 0 0 10 2
3 COMPONENT 40HTS ZENITH 16-16 ARA 006 SEPANG 090 MXHT     0 UNOISE   143 VNOISE   115 WNOISE   135
ANTENNA STATUS:FAULT AC STATUS: OFF BATTV  3.931
```

HT	SPD	DIR	W	SDW	IW	GSPD	GDIR	U	SDU	NU	IU	SNRU	V	SDV	NV	IV	SNRV	NW	SNRW
200	99.99	9999	99.99	99.99	130	99.99	9999	99.99	99.99	0	144	2	99.99	99.99	0	115	2	0	3
195	99.99	9999	99.99	99.99	141	99.99	9999	99.99	99.99	0	135	2	99.99	99.99	0	110	2	0	3
190	99.99	9999	99.99	99.99	144	99.99	9999	99.99	99.99	0	131	2	99.99	99.99	0	109	2	0	4
185	99.99	9999	99.99	99.99	137	99.99	9999	99.99	99.99	0	129	2	99.99	99.99	0	104	2	0	2
180	99.99	9999	99.99	99.99	145	99.99	9999	99.99	99.99	0	144	2	99.99	99.99	0	101	2	0	3
175	99.99	9999	99.99	99.99	142	99.99	9999	99.99	99.99	0	131	2	99.99	99.99	0	108	2	0	2
170	99.99	9999	99.99	99.99	131	99.99	9999	99.99	99.99	0	121	2	99.99	99.99	0	101	2	0	2
165	99.99	9999	99.99	99.99	141	99.99	9999	99.99	99.99	0	124	2	99.99	99.99	0	99	2	0	3
160	99.99	9999	99.99	99.99	136	99.99	9999	99.99	99.99	0	130	2	99.99	99.99	0	116	2	0	3
155	99.99	9999	99.99	99.99	136	99.99	9999	99.99	99.99	0	121	2	99.99	99.99	0	109	2	0	3
150	99.99	9999	99.99	99.99	129	99.99	9999	99.99	99.99	0	120	2	99.99	99.99	0	100	2	0	3
145	99.99	9999	99.99	99.99	130	99.99	9999	99.99	99.99	0	120	2	99.99	99.99	0	96	2	0	3
140	99.99	9999	99.99	99.99	124	99.99	9999	99.99	99.99	0	115	2	99.99	99.99	0	93	2	0	3
135	99.99	9999	99.99	99.99	122	99.99	9999	99.99	99.99	0	105	2	99.99	99.99	0	90	2	0	3
130	99.99	9999	99.99	99.99	122	99.99	9999	99.99	99.99	0	107	2	99.99	99.99	0	79	2	0	3
125	99.99	9999	99.99	99.99	116	99.99	9999	99.99	99.99	0	121	3	99.99	99.99	0	86	3	0	3
120	99.99	9999	99.99	99.99	113	99.99	9999	99.99	99.99	2	134	4	99.99	99.99	0	85	4	0	3
115	99.99	9999	99.99	99.99	122	99.99	9999	99.99	99.99	1	127	4	99.99	99.99	0	82	4	0	4
110	99.99	9999	99.99	99.99	127	99.99	9999	99.99	99.99	2	144	4	99.99	99.99	0	94	4	0	4
105	99.99	9999	99.99	99.99	119	99.99	9999	99.99	99.99	2	146	4	99.99	99.99	2	101	4	1	4
100	8.65	218	99.99	99.99	124	9.88	218	4.53	0.14	3	141	4	7.37	0.38	3	109	4	2	4
95	99.99	9999	1.10	0.22	132	8.92	223	3.98	0.32	4	136	4	99.99	99.99	2	110	4	3	4
90	99.99	9999	1.05	0.48	149	4.83	214	1.38	0.46	5	157	6	99.99	99.99	1	116	6	5	5
85	4.66	201	1.24	0.40	152	10.01	199	1.24	0.48	7	171	6	4.49	0.15	3	126	6	6	6
80	5.57	210	1.20	0.42	160	8.55	204	2.29	0.55	8	186	7	5.08	0.37	9	142	7	6	6
75	3.16	200	0.91	0.35	183	7.24	238	0.79	0.43	8	193	8	3.06	0.47	10	146	8	12	8
70	2.60	197	0.84	0.48	199	10.32	227	0.49	0.49	10	223	9	2.55	0.51	11	155	9	13	9
65	3.24	201	0.65	0.52	208	6.67	219	0.82	0.38	13	253	11	3.13	0.55	11	171	11	14	10
60	2.77	207	0.62	0.46	254	5.90	224	0.99	0.42	14	244	11	2.59	0.75	11	180	11	15	12
55	2.69	205	0.51	0.40	274	5.28	228	0.88	0.28	14	232	10	2.55	0.61	14	197	10	15	12
50	3.08	208	0.40	0.47	333	6.10	233	1.14	0.49	13	278	12	2.86	0.40	14	224	12	15	15
45	2.84	207	0.28	0.53	344	5.00	213	1.02	0.41	15	363	16	2.64	0.50	15	248	16	15	16
40	3.78	217	0.12	0.61	305	6.66	231	1.96	0.46	14	447	18	3.23	0.35	14	250	18	15	15
35	3.83	221	0.07	0.59	296	6.41	216	2.22	0.50	15	489	17	3.12	0.36	15	274	17	15	17
30	3.27	222	0.06	0.45	318	5.83	224	1.91	0.45	15	432	16	2.65	0.25	15	283	16	15	14
25	1.58	265	0.02	0.24	627	2.71	269	1.55	0.33	15	517	18	0.31	0.15	15	797	18	15	16
20	0.77	242	0.18	0.25	795	2.49	234	0.64	0.30	15	515	16	0.43	0.15	15	802	16	15	31
15	1.20	349	0.24	0.26	851	2.62	309	0.35	0.30	14	664	13	-1.15	0.32	13	1239	13	15	20
10	3.95	315	99.99	99.99	1437	4.65	311	3.09	0.24	15	1865	8	-2.46	0.25	15	3295	8	0	3
5	4.15	313	99.99	99.99	1967	4.64	334	3.32	0.18	15	1820	8	-2.49	0.12	15	3309	8	0	5

D Sodar Header Information

Table 10: The different terms in the miniSodar header for each time block.

Line 1			
1	Site Name		
2	Start Date/Time		
3	End Date/Time		
4	SW version		
5	freq	Transmit frequency	Hz
6	bw	Filter bandwidth	Hz
7	damp	% Amplitude level	%
8	pulw	Transmit pulse width	millisecond
9	rise	Pulse shading	millisecond
10	rofs	In phase offset	millivolt
11	jofs	Quadrature offset	millivolt
Line 2			
1	sec	Wind table time reporting interval	seconds
2	avdst	Wind table altitude reporting interval	meters
3	amp	Fixed amplitude threshold	millivolt
4	snr	Signal to Noise threshold	
5	back	Noise sample collection time	millisecond
6	noms	Not used	
7	nwt	Not used	
8	gd	Percent good threshold	%
9	nfft	Number of FFT points	
10	srate	Digital sampling rate	Hz
11	clut	Ground clutter rejection flag	
12	nbini	Signal search window	# points
13	ngav	Number of pulses for gust detection	
14	mincr	C Beam spectra search limit (lower)	radial m/s
15	maxcr	C Beam spectra search limit (upper)	radial m/s
16	minbr	B Beam spectra search limit (lower)	radial m/s
17	maxbr	B Beam spectra search limit (upper)	radial m/s
18	minar	A Beam spectra search limit (lower)	radial m/s
19	maxar	A Beam spectra search limit (upper)	radial m/s
20	wdog	Watchdog timer (enable flag)	
21	mxdel	Mixing height amplitude detection threshold	millivolt
22	ptdir	Sodar reference fram rotation angle	degrees
23	wmax	Vertical velocity detection threshold	m/s
24	phase	Interelement spacing	
25	speci	S file output interval increment	
26	specl	S file number of levels output	
27	specm	S file flag to detail number of axes recorded	
28	specn	S file number of pulses averages	
29	specs	S file index of first level recorded	
30	cdia	DFS data axis	
31	cdid	DFS number of SRATE samples per level	
32	cdin	DFS number of pulses per record	
Line 3			
1	Axes	Number of active beams	
2	Levels	Number of asampling altitudes	
3	ZenithV	Zenith angle of V beam	deg
4	ZenithU	Zenith angle of U beam	deg
5	Rotation	Sodar antenna rotation angle	deg
6	Seperation	Deviation of sodar reference from orthogonal orientation	deg
7	mixHt	Detected mixing height	meters
8	rmnU	Noise sample for X beam	millivolt
9	rmnV	Noise sample for Y beam	millivolt
10	rmnW	Noise sampler for Z beam	millivolt
11	Antenna status	(optional) status of antenna	
12	AC status	(optional) of UPS	
	(Optionally)		
13	AnemometerTemp	(optional) anemometer temperature	deg C
14	Battery Voltage	(optional) ASP battery voltage (DC systems only)	0.25

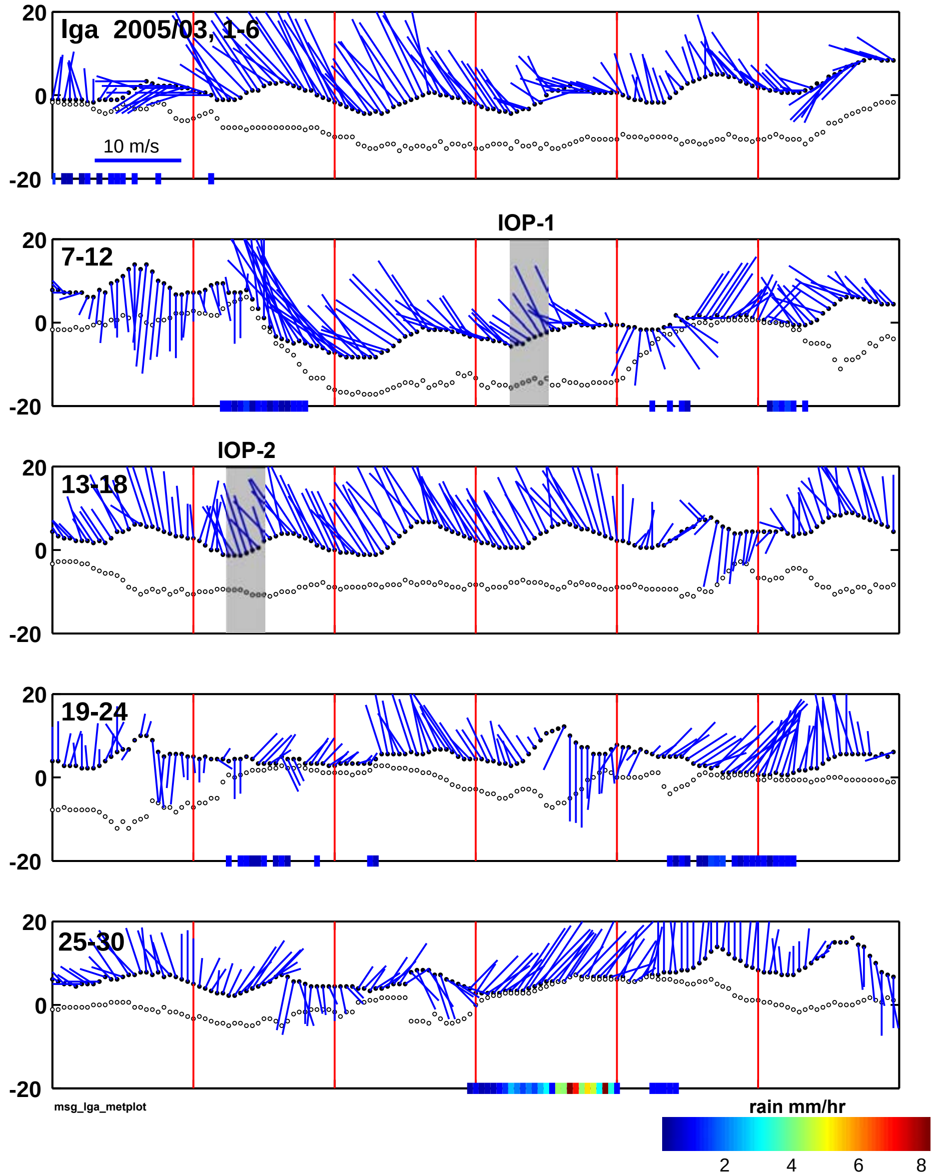

Figure 14: LGA winds for March 2005.

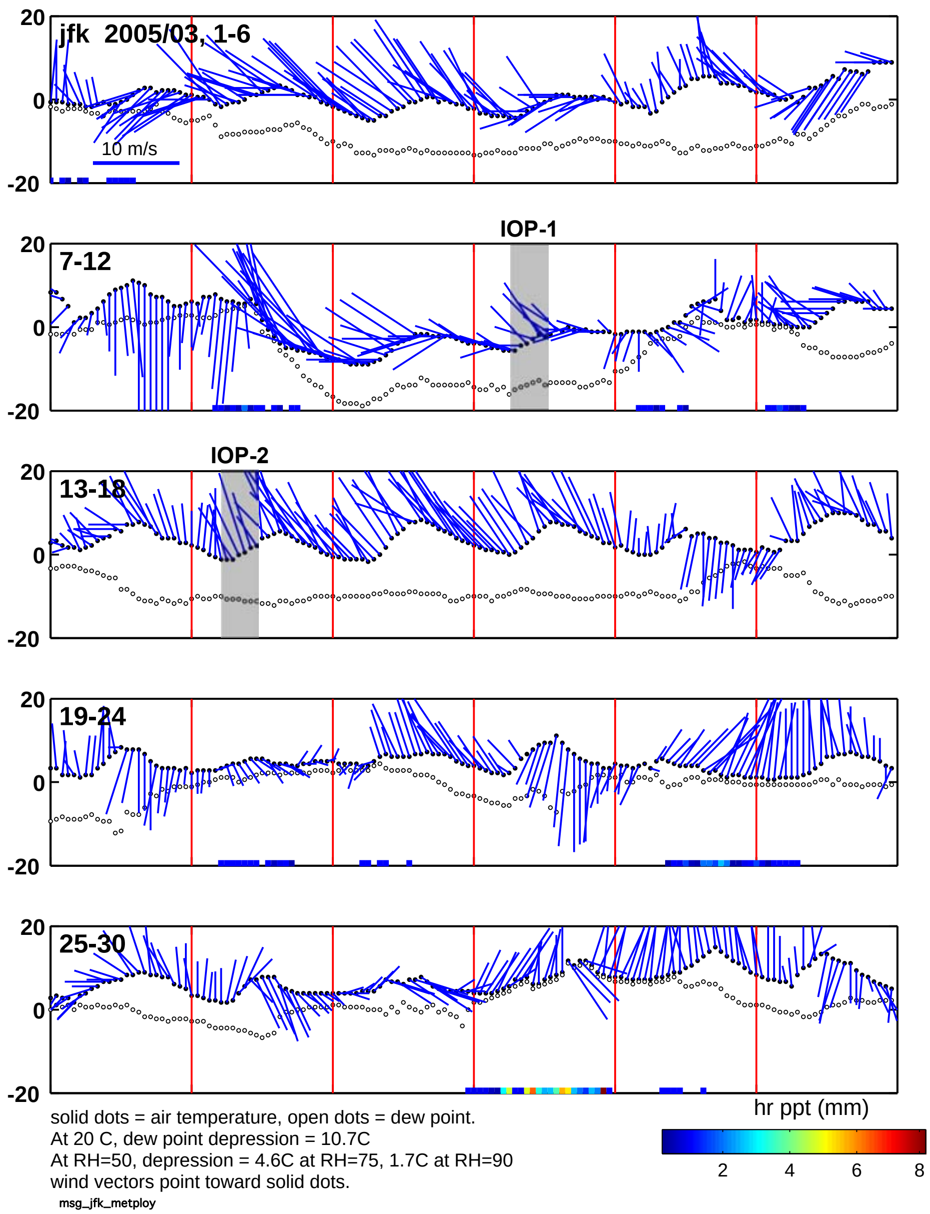

Figure 15: JFK winds for March 2005.

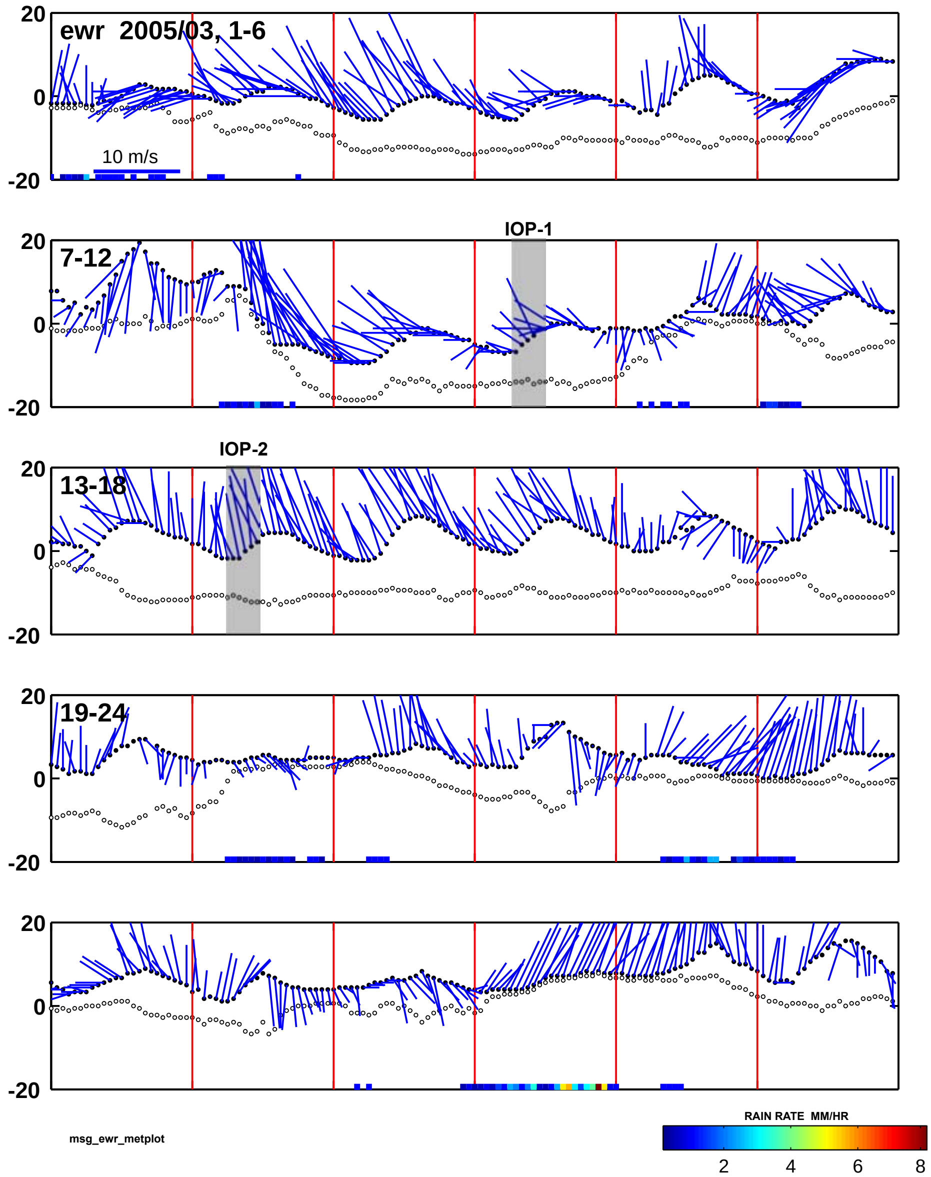

Figure 16: EWR winds for March 2005.

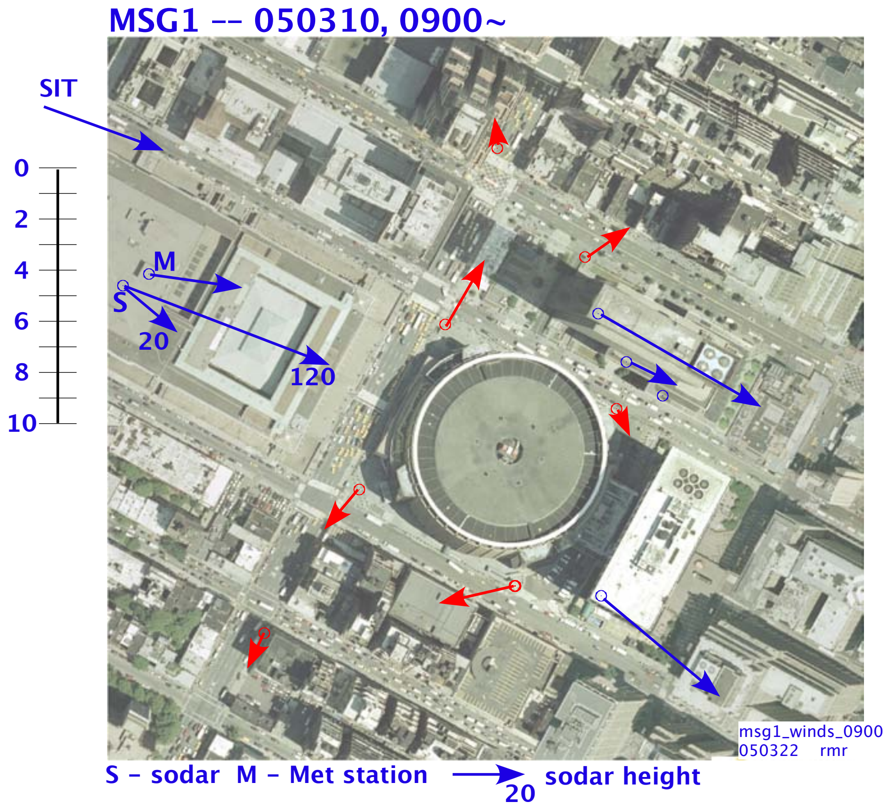

Figure 17: Measured wind fields at 0900 in IOP-1.

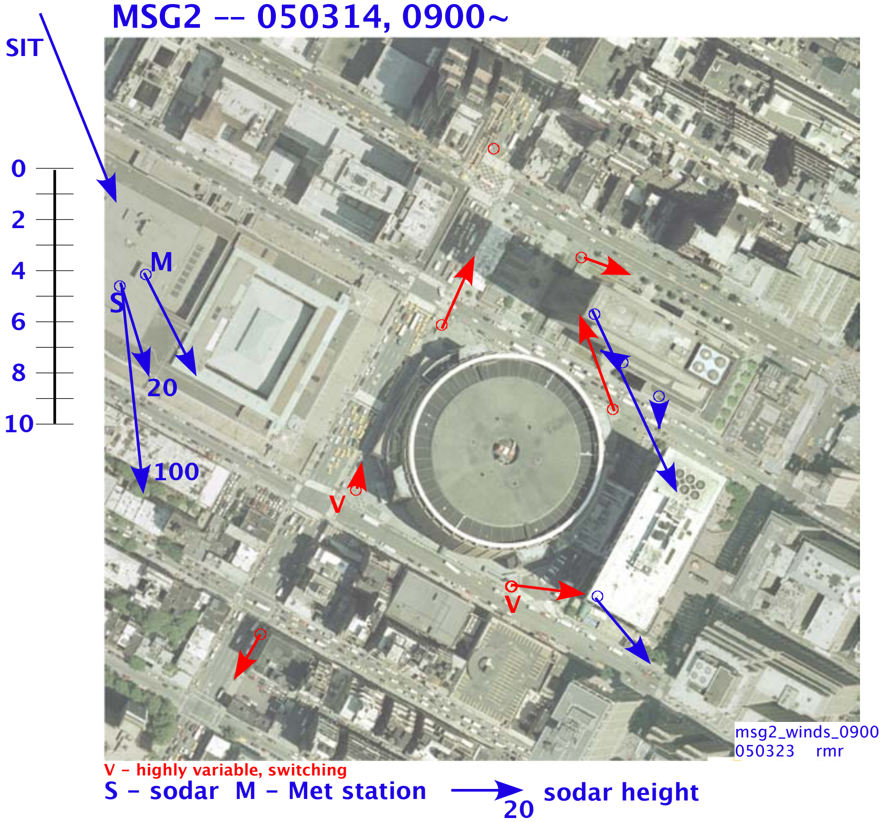

Figure 18: Measured wind fields at 0900 in IOP-2.